Fermilab

R.P. Note #26

Calibration of MERL Long Counter with a Pu-Be Source

J. D. Cossairt

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A plutonium-beryllium neutron source was used to measure the detection efficiency of the precision Long Counter located in the Fermilab Mobile Environmental Radiation Laboratory (MERL) which is used to measure the intensity of neutron radiation fields outside of thick shielding. An extensive description of such a Long Counter is given by DePangher and L.L. Nichols[1] while I.M.G. Thompson and A. Lavender[2] give extensive calibration data. It is not the purpose of the present paper to duplicate the detailed descriptions of Refs. 1 and 2, however, a brief functional description is in order. Fig. 1 from Ref. 1 shows the construction of the detector. Neutrons are moderated by the polyethylene shielding to thermal energies. The BF_3 tube is a gas proportional counter which is enriched to 96% ^{10}B. The $^{10}B(n, \alpha)^7Li$ reaction has a large thermal neutron cross section, (3838 barns). The ^7Li nucleus is left in its 478 keV first excited state 95 per cent of the time, while it is in the ground state 5 per cent of the time (Ref. 1). The α + ^7Li system share 2.9 MeV which is released in the reaction (including the 478 keV gamma ray) and produce a signal which is large relative to competing photon and charged particle (muon) radiation in a mixed field of the type encountered at Fermilab.

The original designers of the detector "fine-tuned" the moderator until an efficiency reasonably independent of neutron energy over a fairly large domain was obtained. Fig. 2 (from Ref. 2) is typical of the efficiency as a function of energy. The efficiency is thus flat over 3 decades of energy and is the reason for the name "Long Counter". To achieve this property the detector must have the front face oriented toward the source of the radiation.

The Long Counter installed in the MERL is somewhat unique in that it is installed in a housing consisting of 3 inches of plywood arranged in a rather complicated geometry comprising wheel wells, walls, etc. The goal of the present work was to measure the response of this detector exposed to a source of neutron outside of the MERL. Fig. 3 shows a block diagram of the electronics along with settings used here. The first measurement consisted of determining the proper threshold to use on the TC213 to discriminate against unwanted gamma rays while counting neutron induced pulses with good efficiency. To accomplish this, the count rate was measured as a function of discriminator threshold for both ^{60}Co source and a plutonium-beryllium (Pu-Be) neutron source. The decay of ^{60}Co is dominated by the emission of 1.17 and 1.32 MeV gamma rays. By comparison, minimum ionizing muons would deposit about 0.2 MeV in traversing the length of the BF_3 proportional counter. This is indeed small compared with the 2.9 MeV deposited due to neutron capture. The spectrum of the Pu-Be source has been reported in Patterson and Thomas[3] and has an average neutron energy of 4.1 MeV. Fig. 4 shows graphs of count rate as a function of threshold for both sources. It is seen that the neutron efficiency is independent of threshold except at very low values. The plutonium source (^{238}Pu) emits gamma rays (less than 150 keV) of which some are seen at low values of the threshold setting. Of course, some 478 keV gammas are also detected due to the deexitation of ^{7}Li. A threshold setting of about 3 volts is a reasonable choice to achieve good neutron efficiency while removing the gammas (and hence muons in a Fermilab mixed field).

After determination of the threshold setting it was desired to measure the count rate in a known neutron field. The neutron field chosen was that of a ^{238}Pu-Be source calibrated by the National Bureau of Standards to emit 4.11×10^6 neutron/sec. The count rate was measured at varying distances of the source from the face of the long counter through the side of the MERL vehicle, thus including the attenuation of the wooden walls of the MERL. Table I shows the results obtained. The distances are measured from the effective center of the counter (see Ref. 2) which is approximately 12 cm inside the front face for an average neutron energy of 4.1 MeV. As one can see, the results in reasonable (10%) agreement with "inverse square law" expectations. Some deviation from inverse square behavior would not be surprising due to the fact that the apparatus is about 4 ft above ground level so that a convenient scattering surface (the earth) is present.

It is now possible to evaluate the efficiency of the long counter in this field since the source strength is known. The results are shown in Table I. The result of 4.3 $\frac{\text{counts}}{\text{n/cm}^2}$ is in reasonable (20%) agreement with results reported in Ref. 2 where a value 3.6 counts/(n/cm^2) was reported. The higher value found here may well be due to the increased quantity of thermalizing material presented by the wooden walls.

For Pu-Be neutrons, Ref. 3 (p 69) gives a value of 6.9 neutrons/(cm$^2\cdot$sec)/(mrem/hr) (quality factor of 8 included) so that the long counter will respond in such a field by 1.07×10^5 counts/mrem or 8.56×10^5 counts/mrad.

Table I

R (cm)	Field n/(cm^2·sec)	Long Counter Response (counts/sec)	Ratio (count/n/cm^2)
100	32.7	121.7	3.72
200	8.12	33.8	4.13
300	3.63	15.3	4.21
400	2.04	8.85	4.33
500	1.31	5.6	4.32

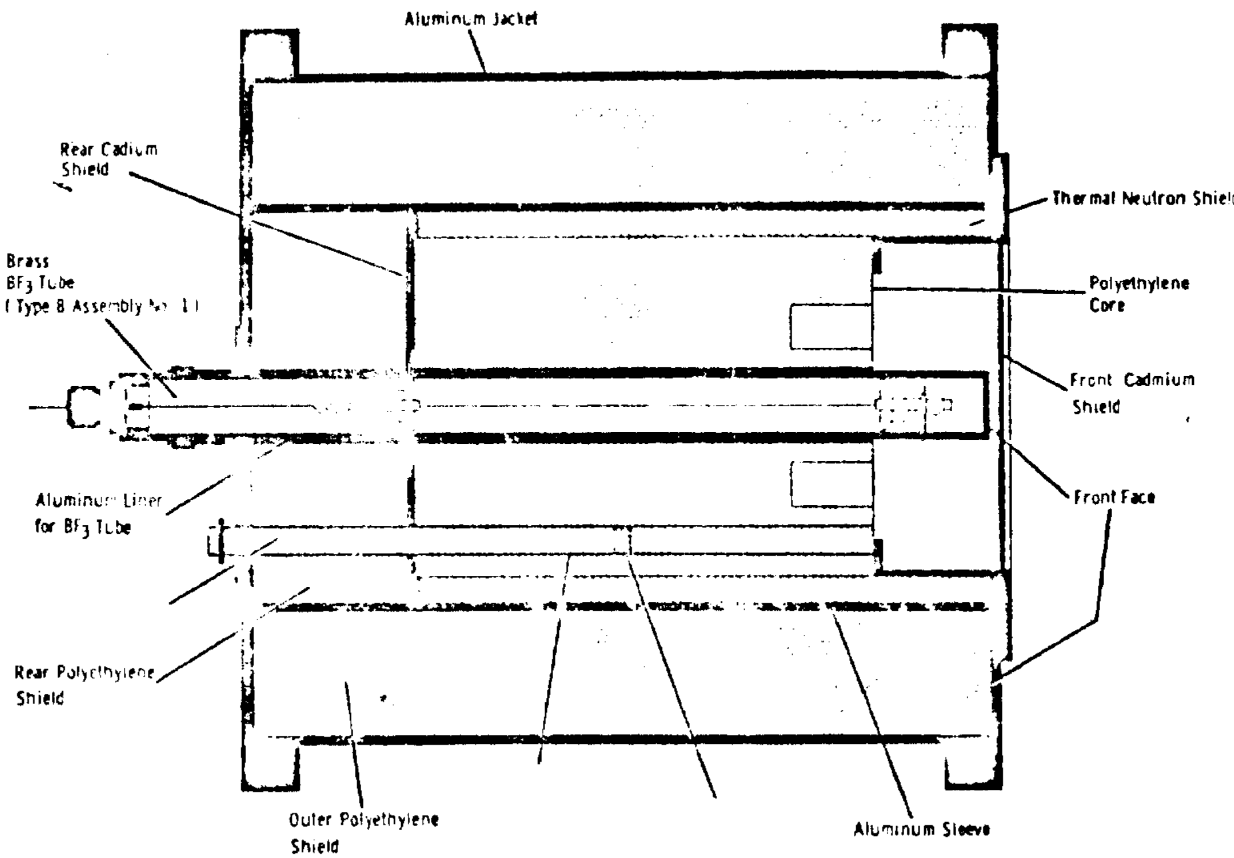
List of Figure Captions

References

1. J. DePangher and L.L. Nichols, Battelle Northwest Laboratories Report BNWL-260, June 1966.

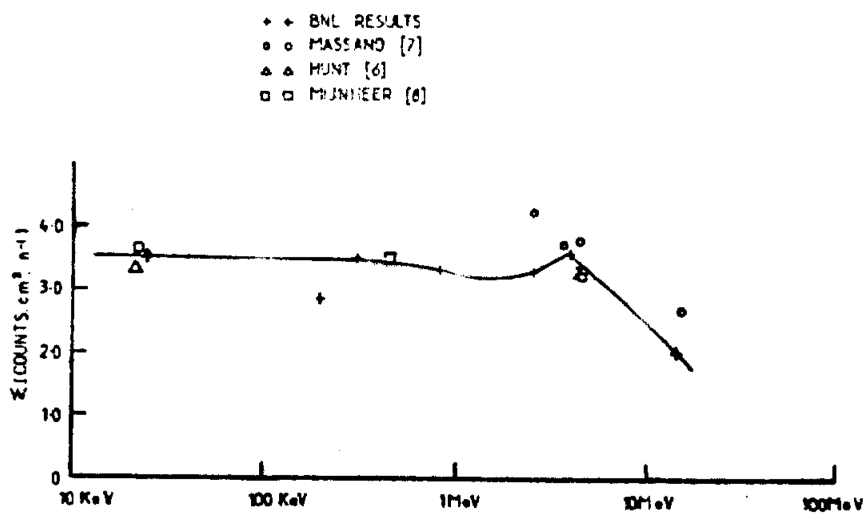
2. I.M.G. Thompson and A. Lavender, IAEA Symposium on Neutron Monitoring for Radiation Protection Purposes, Vienna, 1972, IAEA/SM-167/42.

3. H.W. Patterson and R. H. Thomas, Accelerator Health Physics, (Academic Press, New York, 1973).



Aluminum Jacket
Rear Cadium
Shield
Thermal Neutron Shield
Brass
BF_3 Tube
Polyethylene
Core
Front Cadmium
Shield
Aluminum Liner
for BF_3 Tube
Front Face
Rear Polyethylene
Shield
Outer Polyethylene
Shield
Aluminum Sleeve

Figure 1



LONG COUNTER EFFICIENCY

Figure 2

LONG COUNTER ELECTRONICS

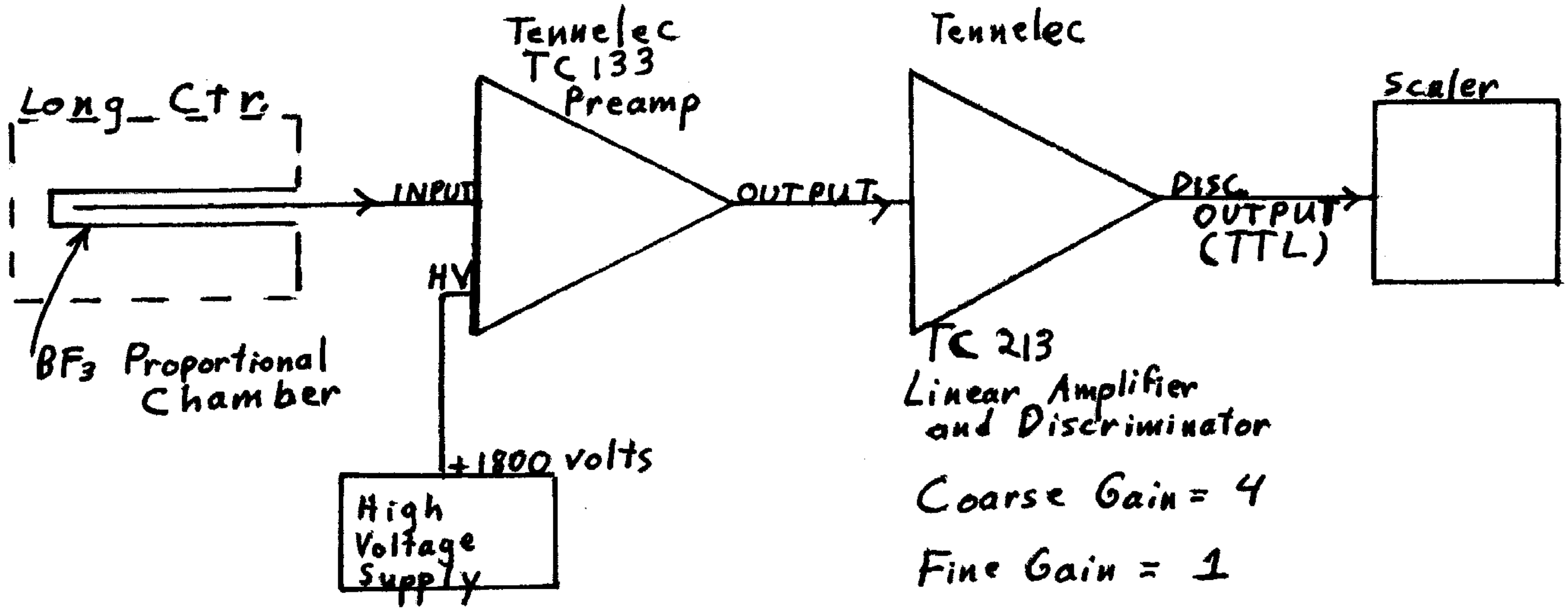
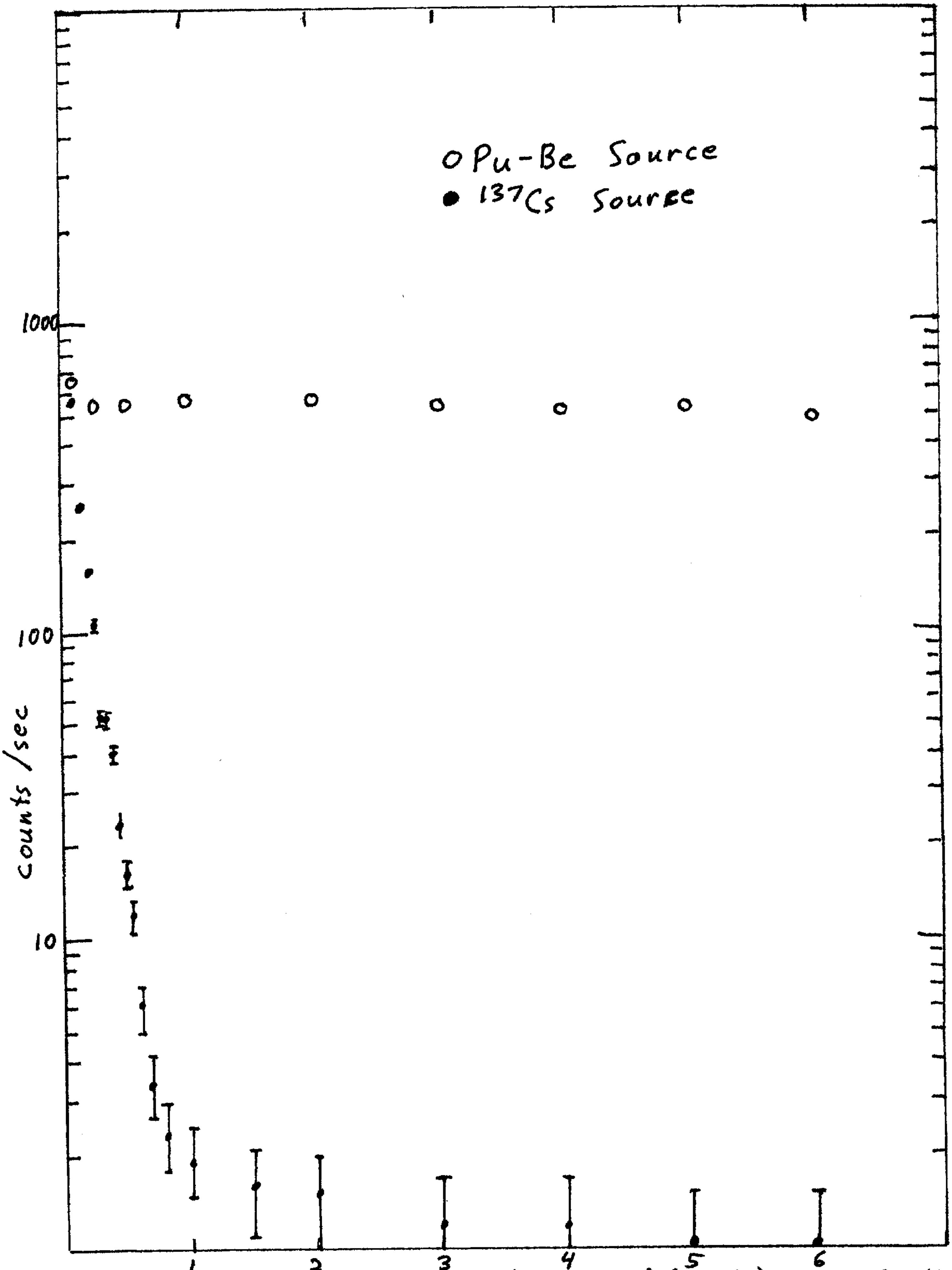


Figure 3



Threshold (TC 213) (Volts)

Fig 4